

ASIRI: Air-Sea Interactions in Northern Indian Ocean (And it's Relation to Monsoonal Dynamics of the Bay of Bengal)

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LONG-TERM GOALS

The long term goal of this project is to help develop collaboration between two South East Asian Countries (Sri Lanka and India) and the US for tackling scientific problems related to air-sea interactions in the Bay of Bengal (BOB), especially in relation to Indian Ocean Monsoons (IOM) and their breaks. Monsoons are caused by large amplitude land-ocean temperature differentials resulting from the seasonal cycle of solar forcing on oceans and land. The IOMs are strongly modulated by air-sea interactions, particularly in the BOB, thus determining sub-seasonal variability of the region. The summer monsoons are southwesterly, the resulting BOB circulation is anticyclonic, and strong upwelling occurs along the western boundary of BOB. Modulations of air-sea interactions, among other factors, lead to recurring monsoon breaks sandwiched between active wind periods. In the autumn, the monsoon winds switch to northeasterly, leading to the reversal of ocean currents, which occurs through a set of dynamical adjustments. The broad goals of this project is to (i) undertake a comprehensive review of previous studies on air-sea interactions in BOB, (ii) identify critical science issues that underpin a future comprehensive oceanographic research program on BOB, (iii) identify and initiate collaboration with a group of regional (Indian and Sri Lankan) scientists, (iii) visits to key institutions in India and Sri Lanka to facilitate collaboration, (iv) initiate a scientific personnel exchange program with these countries and the USA to cross-pollinate scientific expertise, (v) identify and address key administrative and intergovernmental bottlenecks for future research partnerships, (vi) help organize scientific meetings in India and Sri Lanka to plan for future collaborative programs of mutual interest, (vii) initiative outreach and capacity building efforts, and (viii) help ONR in developing regional research initiatives.

OBJECTIVES

The current project seeks to identify key scientific issues that help develop future ONR initiatives on BOB, establish research cooperation with India and Sri Lanka, initiate three-way exchange programs and organize scientific workshops to address issues pertinent to future research efforts. Given the multinational nature of the anticipated BOB program, interfacing and negotiating with respective governmental agencies and research organizations deem necessary, overcoming administrative hurdles. The science component of the current project includes preparation of collaborative journal articles with

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Sri Lankan and Indian scientists as well as preliminary laboratory experiments dealing with circulation induced by mountains subject to differential thermal forcing, as encountered in IOMs.

APPROACH

The work constitutes of the following tasks: (i) establishing a steering group consisting of US scientists with ties to India and Sri Lanka, (ii) arranging visits to partner countries and establishing contacts with relevant agencies, ministries and NGOs, (iii) initiation of exchange visits between key institutions, which will cover training of individuals as needed and preparation of a reviews on IOM research, (iv) identifying and addressing critical logistical issues and show-stoppers of future activities, (v) Initiate research work with Indian and Sri Lankan scientists related to oceanographic research, in particular on air-sea interactions during IOMs.

WORK COMPLETED

During the FY 2012, the following was completed.

Visit of Mr. Priyantha Jinadasa from NARA (August 23, 2011 – February 22, 2012): Mr. Jinadasa, a research officer at NARA, visited Notre Dame. He participated in several graduate courses and conducted research for his PhD thesis. Mr. Jinadasa was also a recipient of a POGO (Partnership for Observation of the Global Oceans) fellowship to visit Notre Dame.

Meeting with Sri Lankan Ambassador in Washington DC (November 21, 2011): The meeting was attended by ONR and NRL Officials as well as by the PIs. The agenda included discussions on possible reclassification of Sri Lankan ports from Risky to Safe status by the US State Department. This status change was imperative for the US vessel R/V Roger Revelle to operate out of Sri Lankan ports. Also we requested support for a US AID Proposal to acquire state-of-the-art instrumentation for the National Aquatic Resources Research and Development Agency (NARA) in Sri Lanka. Discussions were also held on possible operation of US research vessels in Sri Lankan waters.

Formulation and Execution of a MOU between NARA and University of Notre Dame (UND): This MOU was prepared jointly by NARA and UND, and included clauses on the nature of collaboration, access of US research vessels and exchange visits between Sri Lanka and the US.

New Orleans Meeting (January 20, 2012): Following the approval of ASIRI (Air Sea Interaction of Northern Indian Ocean) - DRI, a Regional Initiative focusing on Sri Lanka and surrounding waters, a meeting was held to discuss the science plans for the initiative. Several university investigators were invited by the ONR for this meeting. The location was selected to facilitate participation of NRL scientists, given the plans of NRL to join ASIRI. The NRL initiative is dubbed E-BoB, and their field work will be conducted jointly with ASIRI.

A Proposal to Acquire Instrumentation for NARA (March 2010): A proposal was submitted by NARA (aided by the PI and NRL) to the Sri Lanka Foreign Ministry to acquire instrumentation for research related to ASIRI via the US AID Program.

Capacity Building at NARA through a Lecture Series (March 23- April 23, 2012): PI's colleague, Research Professor Iossif Lozovsky, visited Sri Lanka for one month to conduct a special lecture

series on physical oceanography, in particular, turbulence and waves in ocean. His visit also was partly funded by the POGO Visiting Professorship Program.

ONR-Global Proposal (March 2012): A proposal was submitted by the PI to ONR-Global to hold a workshop in Sri Lanka during April 18-20, 201 to discuss science plans for the ASIRI Project.

Meeting in Sri Lanka with NARA Officials (March 8, 2012): Following the Monsson Mission meeting in Bangalore, the PI visited NARA officials to discuss the status of collaboration, in the wake of the changes of NARA administration. The April meeting was postponed till a new path forward is found.

Visit of Prof. G.N. Bhat (March 18 – April 29, 2012): Prof. Bhat from the Center for Atmosphere and Ocean Sciences (CAOS) visited the PI for establishing collaboration. He also visited WHOI and University of Massachusetts for establishing further collaboration.

Meeting with Sri Lankan Defense Officials and Fisheries Ministry (June 27-30, 2012): The PI and a NRL colleague visited Sri Lanka to discuss collaborative arrangements on the ASIRI project; two meetings were held with the Sri Lanka Navy Commander and his vice admirals and a meeting was held with the new Chairman of NARA. New strategies for the collaboration were discussed.

Organization of a ASIRI-DRI Meeting in Colombo (November 28-30, 2012): A meeting has been organized to discuss joint US-Sri Lanka research in conjunction with ASIRI and E-BOB initiatives. The meeting is a part of the First International Conference on Oceanography in the Bay of Bengal.

RESULTS

During the visit of Mr. Priyantha Jinadasa from NARA, data sets taken during other projects (e.g., N00014-10-1-0738) was analyzed to deduce velocity structure functions, and the results were compared with theoretical formulations. Mr. Jinadasa also participated in several meetings, including one at WHOI dealing with Indian Ocean Monsoons and at the January 20th meeting in New Orleans. Mr. Jinadasa also was provided with floats by Dr. Luca Centurioni from SIO, which were deployed in the southern Sri Lanka.

The meeting with the Sri Lanka ambassador helped in reclassifying Sri Lanka ports as “safe”, which was officially announced by the US Coast Guard on January 17, 2012. The MOU between NARA and UND was executed on December 8th, and the lecture series at NARA under the POGO professorship program was a great success (POGO Newsletter 2012). The ONR Global proposal was funded, and the postponed meeting has been rescheduled for November 28-29, 2012. Discussions with NARA and defense officials in Sri Lanka have made strides toward a mutually amicable solution for future collaborative field programs and joint research.

During the visit of Mr. Jinadasa to UND, research on intermittency correction factor for the Obukhov-Corrsin “-5/3” inertial-convective subrange spectral law was estimated using conductivity (temperature) fluctuation measurements conducted within microstructure patches of oceanic pycnocline. Its value was found to be in the range 0.46 – 0.51, depending on the accuracy of calculation, which is applicable to stratified, low Reynolds-number oceanic turbulence. The intermittency factor for mesoscale (up to 1 km) lateral variations of scalar dissipation was estimated as 0.43 ± 0.02 . The breakdown mechanisms of small-scale locally isotropic and mesoscale non-isotropic

(lateral) turbulent temperature fluctuations in oceanic turbulence were also studied light of these observations (Jinadasa et al. 2012).

During Professor Bhat's visit to UND, a critical issue of air-sea interactions related to climate predictions was studied. Whilst most coupled climate models (CCMs) predict the opposite, 5-10 Wm⁻² of heat flows from air to water over parts of Indian, Pacific and Atlantic Oceans during summer monsoons or high wind periods (Bhat & Fernando 2012). This requires sea-air temperature difference to be negative, which models fail to predict correctly. It was suggested that a flow instability phenomenon discovered in laboratory simulations and supported by field observations (Strang & Fernando 2001), namely, resonant hydrodynamic instability mechanism (RHIM), be included in CCMs. RHIM gets activated when a turbulent atmospheric boundary layer (ABL) is capped by a thermally stable layer in the presence of strong wind shear. Wave breaking resulting from RHIM entrains higher entropy air from above and dumps it into ABL over a range of Richardson number well above the classical threshold. RHIM may account for observed air to sea heat flux over open oceans, and its incorporation in CCMs is expected to improve interface fluxes and reduce models' cold temperature bias.

IMPACT/APPLICATIONS

This project immensely contributes to an ONR initiative dealing with air-sea interactions during Indian Ocean monsoons (ASIRI-DRI). It helps establish collaboration between Indian, Sri Lankan and US oceanographic communities.

TRANSITIONS

None. The RHIMS mechanism proposed, however, has potential to be included in coupled climate models.

RELATED PROJECTS

The PI is a co-PI of a project entitled, Mesoscale Dynamics and Lateral and Vertical Mixing in China Seas and Western Pacific, N00014-10-1-0738.

REFERENCES

POGO Newsletter, 2012: Update on POGO capacity building: Visiting Professorship in Sri Lanka Issue 10 (October), pp 3.

E. J. Strang and Fernando, H.J.S., 2001: Entrainment and mixing in stratified shear flows. *J. Fluid Mech.* **428**, 349-386.

PUBLICATIONS

Bhat, G.N. and Fernando, H.J.S., 2012: Resonant Hydrodynamic Instability Physics can Reduce Sea-air Interface Flux Errors in Coupled Climate Models. *Sub judice*.

Jinadasa, S.P.U., Lozovatsky, I.L. and Fernando, H.J.S. 2012: Small-scale and Lateral Intermittency of Oceanic Microstructure in the Pycnocline, *Acta Physica*, In Press.

HONORS/AWARDS/PRIZES

The PI was elected as a Fellow of the American Association for the Advancement of Science (AAAS).